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Title: Development of a Reliable Fuel Depletion Methodology for the HTR-10 Spent Fuel Analysis

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Development of a Reliable Fuel Depletion Methodology for the HTR-10 Spent Fuel Analysis

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Los Alamos National Laboratory

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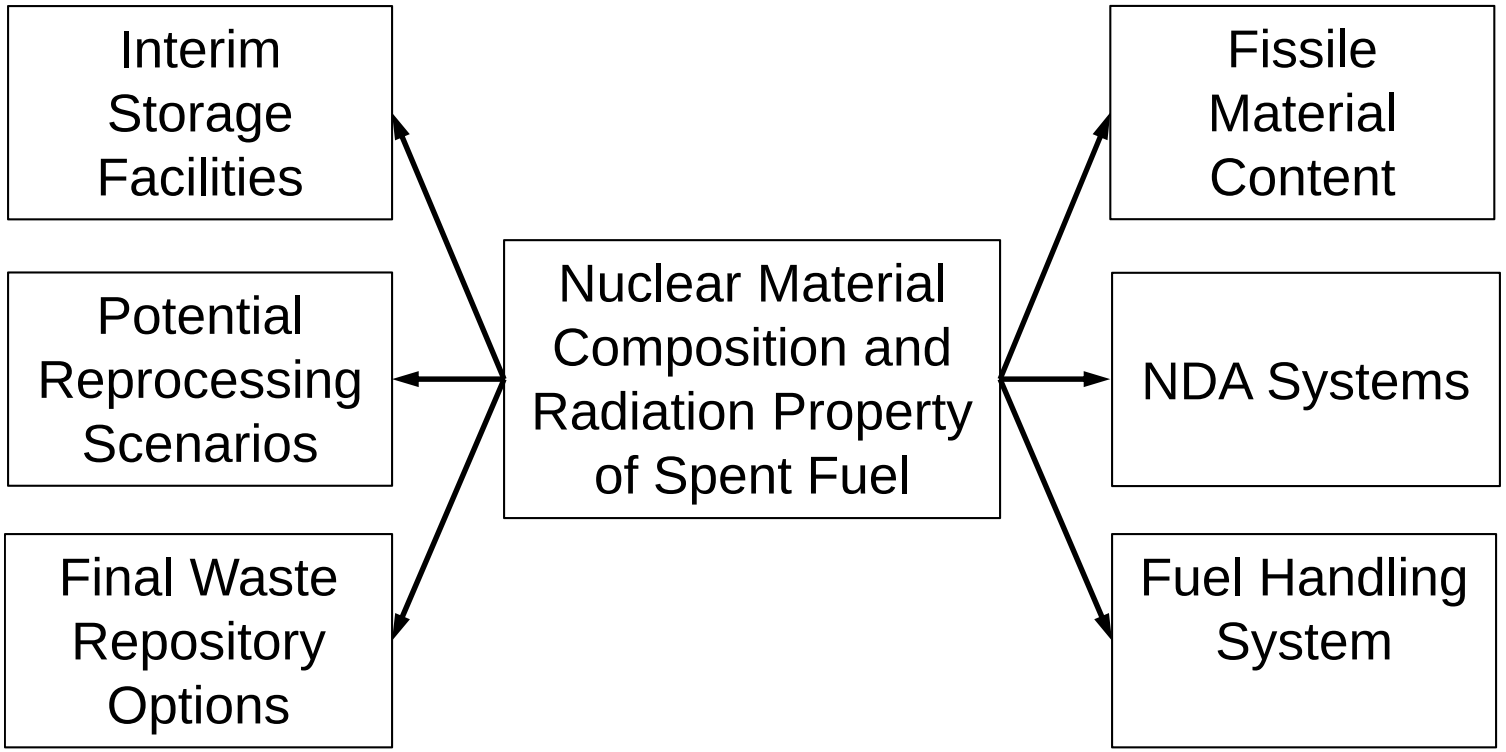
Introduction

- Chinese HTR-10 is the only active and latest reincarnation of PBRs.
- Currently under IAEA safeguards but no final approaches.
- Implementation for the spent fuel and discharge pathways considered.
- Important for HTR-10 and others for export purpose.
- DOE ASA-100 proposed ➔ Need reliable calculation of the composition of fuel pebbles.

Effective Safeguards Approach



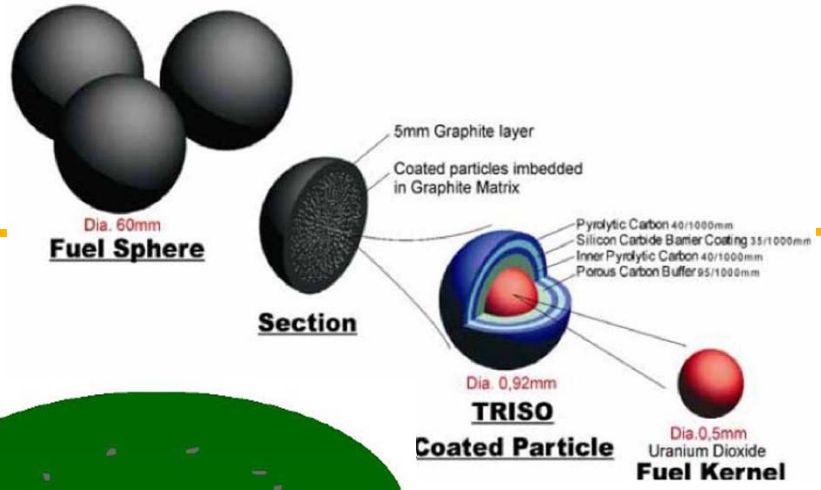
LANL Task

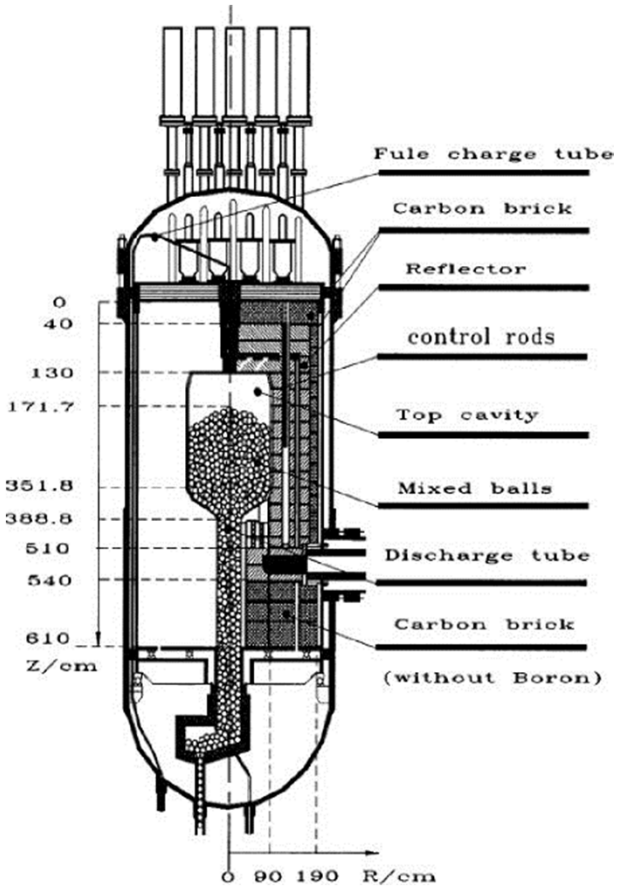
A technical working group formed in 2007 between NNSA and CAEA

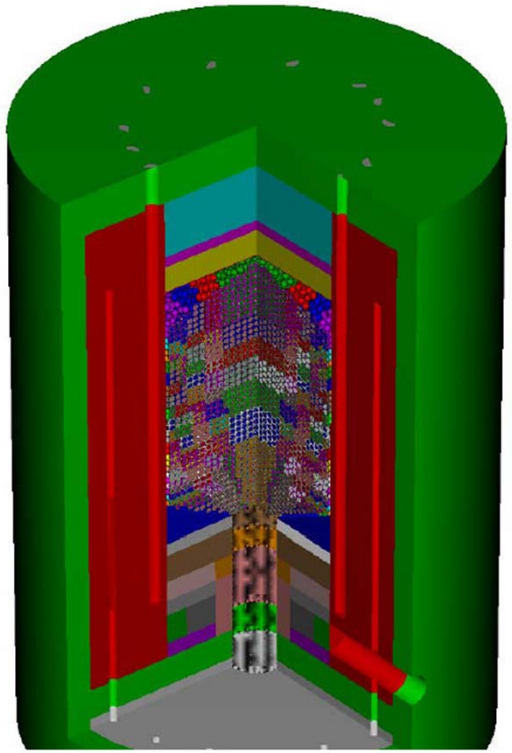
To develop a reliable fuel depletion method for HTR-10 based on MCNPX

To analyze the isotopic inventory and radiation source terms of the HTR-10 spent fuel

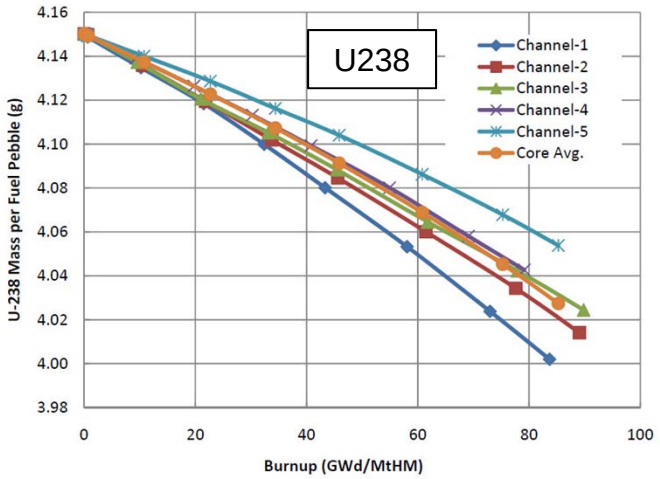
Views of HTR-10

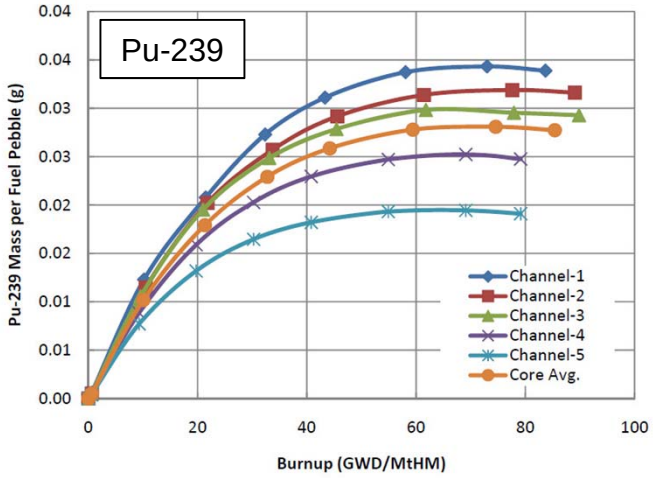


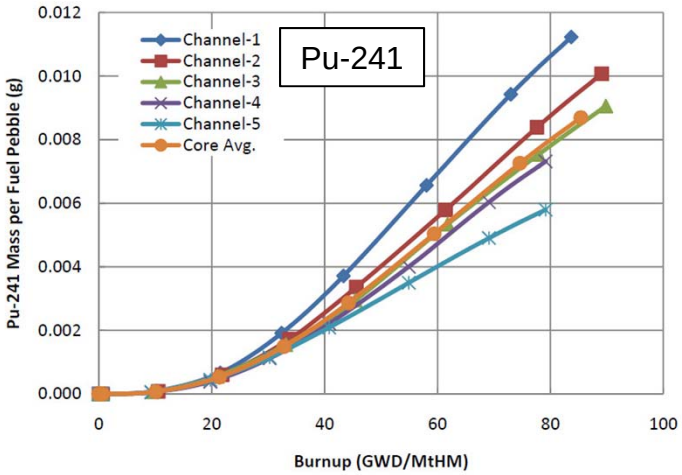




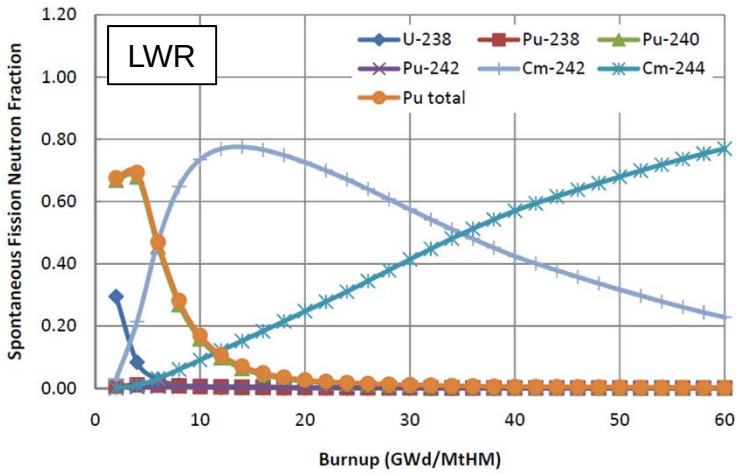
Actinides inventory

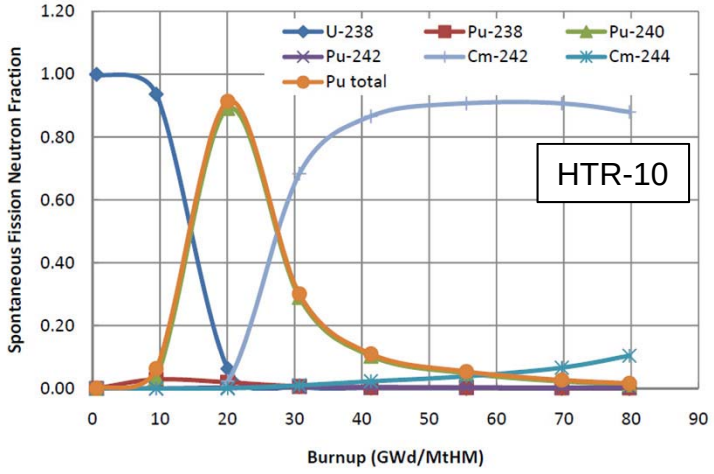


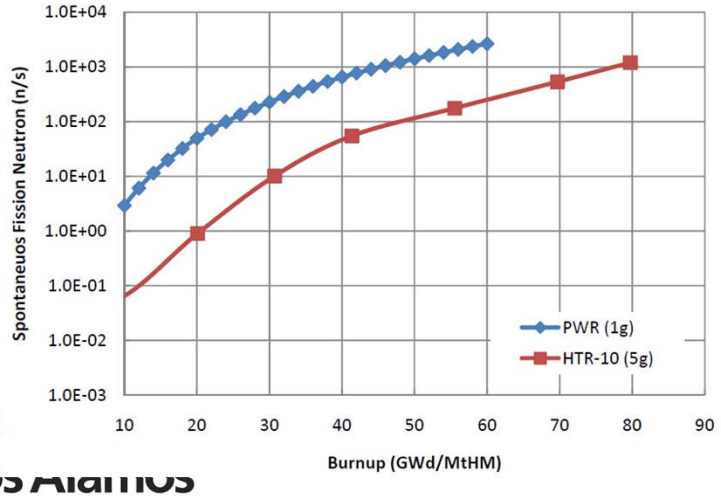


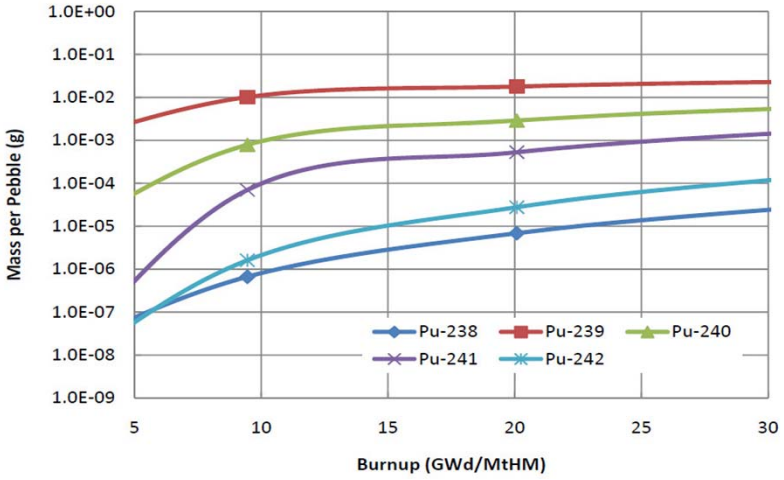


Spontaneous fission neutron signatures of LWR and HTR-10 Spent Fuels

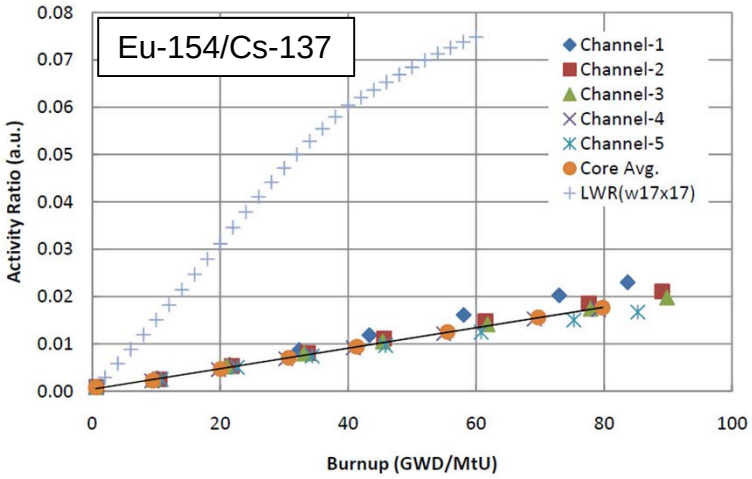


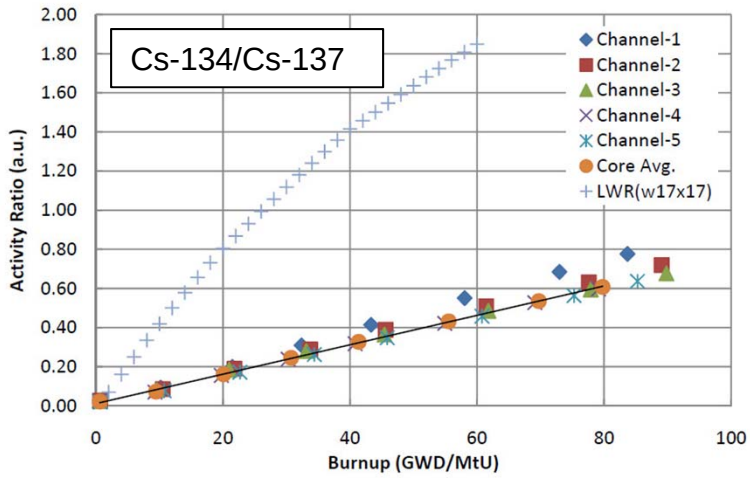






Gamma Activity ratios of Eu-154/Cs-137 and Cs-134/Cs-137





Mass inventory of fissile isotopes in a fully burnt HTR-10 spent pebble

One IAEA Criterion: Pu-238 accumulation not less than 0.8% ➔ safeguards can not be terminated

Between 118,877 and 192,526 pebbles are needed to accumulate 8 kg Pu

Channel	Discharge Mass (g/pebble)						
	U-235	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu Total
Channel 1	4.01E-01	6.85E-04 *(0.010)	3.39E-02 (0.504)	1.79E-02 (0.266)	1.12E-02 (0.167)	3.61E-03 (0.054)	6.73E-02
Channel 2	4.07E-01	5.77E-04 (0.009)	3.16E-02 (0.505)	1.73E-02 (0.276)	1.01E-02 (0.161)	3.13E-03 (0.050)	6.27E-02
Channel 3	4.09E-01	5.10E-04 (0.009)	2.93E-02 (0.502)	1.66E-02 (0.285)	9.06E-03 (0.155)	2.80E-03 (0.048)	5.83E-02
Channel 4	4.16E-01	4.04E-04 (0.008)	2.47E-02 (0.494)	1.54E-02 (0.307)	7.32E-03 (0.146)	2.27E-03 (0.045)	5.01E-02
Channel 5	3.82E-01	4.68E-04 (0.011)	1.91E-02 (0.460)	1.37E-02 (0.329)	5.80E-03 (0.140)	2.50E-03 (0.060)	4.16E-02
Core Avg.	4.03E-01	5.29E-04 (0.009)	2.77E-02 (0.495)	1.62E-02 (0.289)	8.70E-03 (0.155)	2.86E-03 (0.051)	5.60E-02

*Values in parenthesis are the mass fractions of the Pu isotopes.

Self-protecting feature of HTR-10 spent fuel

Dose rate at 1 m from a pebble (rem/hr)								
Core Averaged Burnup (GWD/MtHM)	0.59	9.45	20.09	30.72	41.36	55.54	69.72	79.76
Neutron*	5.99E-11	6.39E-11	9.55E-10	1.07E-08	5.81E-08	1.86E-07	5.65E-07	1.26E-06
Gamma (Cs-137)	0.021	0.056	0.117	0.179	0.240	0.320	0.400	0.456
Total	0.021	0.056	0.117	0.179	0.240	0.320	0.400	0.456
Number of fuel pebble for self-protecting dose rate								
Burnup (GWD/MtHM)	0.59	9.45	20.09	30.72	41.36	55.54	69.72	79.76
IAEA limit (100 rem/hr)	4,804	1,802	853	560	417	313	250	220
DOE limit (20 rem/hr)	961	360	171	112	83	63	50	44

* A point isotropic neutron source of about 2 MeV.

Conclusion

- **Established a fuel depletion methodology and demonstrated its safeguards application**
- **Proliferation resistant at high discharge burnup (~80 GWD/MtHM)**
  - Unfavorable isotopics, high number of pebbles needed, harder to reprocess pebbles
- **SF should remain under safeguards comparable to that of LWR**
- **Diversion scenarios not considered, but can be performed**